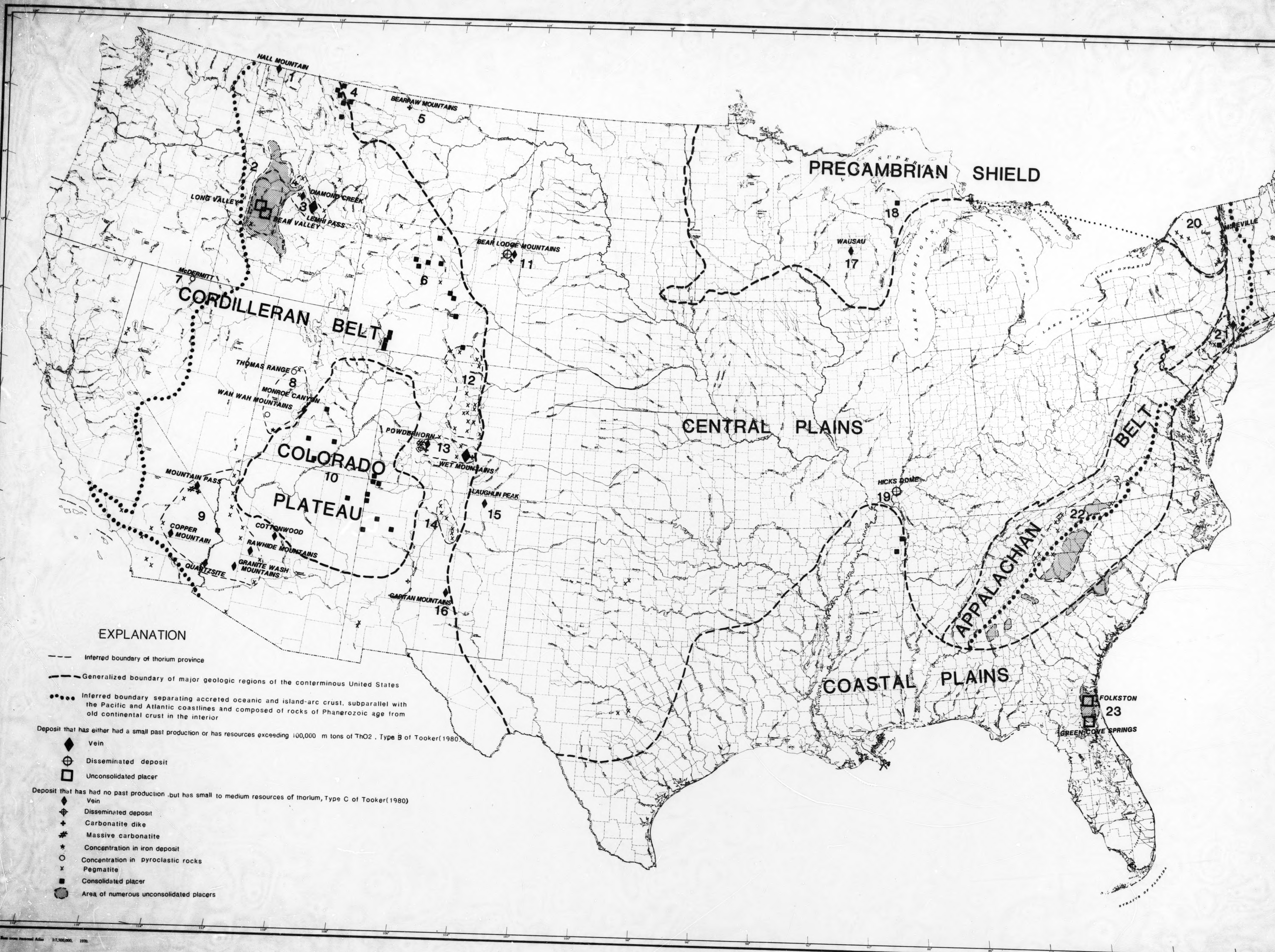
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

ATLAS OF METAL AND NONMETAL MINERAL PROVINCES, CONTERMINOUS U.S.

OPEN-FILE REPORT
79-576U

STAATZ AND ARMBRUSTMACHER—THORIUM



EXPLANATION

- - - Inferred boundary of thorium province

— — Generalized boundary of major geologic regions of the conterminous United States

●●●●● Inferred boundary separating accreted oceanic and island-arc crust, subparallel with the Pacific and Atlantic coastlines and composed of rocks of Phanerozoic age from old continental crust in the interior

Deposit that has either had a small past production or has resources exceeding 100,000 m tons of ThO2 , Type B of Tooker(1980)

◆ Vein
⊕ Disseminated deposit
□ Unconsolidated placer

Deposit that has had no past production ,but has small to medium resources of thorium, Type C of Tooker(1980)

◆ Vein
⊕ Disseminated deposit
✚ Carbonatite dike
Massive carbonatite
★ Concentration in iron deposit
○ Concentration in pyroclastic rocks
× Pegmatite
■ Consolidated placer
▨ Area of numerous unconsolidated placers

Planimetric Base from National Atlas 1:7,500,000, 1970.

INTRODUCTION

[illegible]

The size of the symbol indicates whether a deposit is a small producer or deposit with great potential, type B; or deposits having a small or medium potential, type C. Type A deposits, active mines that had substantial production in the base year 1975 (Tooker, 1980), are not found in the conterminous United States. Type B includes small present and past producers, such as Bear and Long Valleys, Idaho (map no. 2); Folkston, Georgia (map no. 23); and Green Cove Springs, Florida (map no. 23). In all of these deposits the thorium is but a minor byproduct. At these localities thorium recovery was dependent on the recovery of rare earths, and the rare earths were in turn a byproduct of titanium oxide and zircon at Folkston and Green Cove Springs, and of niobium at Bear Valley. Two large disseminated deposits, Bear Lodge Mountains and Hicks Dome (map no. 11 and 19), are also included in type B because of their potential as future producers. Knowledge of this type of deposit is relatively new, being first described by Staatz, and others (1979, p. 20-27). These deposits contain large resources of thorium and rare-earth elements. This type of deposit is analogous to the porphyry-type copper and molybdenum deposits.

One of the most common types of thorium deposits is that found in pegmatites. The thorium content of the entire pegmatites, however, is small. Thorium-bearing pegmatites are probably most important in delineating provinces in which thorium is available to form other types of deposits. The location of the thorium-bearing pegmatites shown on the map was largely derived from a compilation made by Adams and others (1980).

Relation to rare-earth elements

Thorium commonly occurs with rare-earth elements in areas containing alkaline rocks such as massive carbonatites, carbonatite dikes, disseminated deposits, or veins. The total rare-earth to thorium ratios in these districts are highly variable, but in general thorium is much less plentiful than rare earths in the carbonatites, and somewhat more abundant than rare earths in veins. The two also occur together in apatite in iron deposits. Here, rare earths are much more common than thorium.

Description and evaluation of thorium provinces

Province boundaries are drawn around areas where known primary thorium deposits are most abundant. They indicate areas in which thorium deposits are fairly [illegible]

Scale 1:5,000,000
100 0 100 200 300 400 Miles
100 0 100 200 300 400 500 Kilometers

PRELIMINARY MAP OF THE THORIUM PROVINCES
IN THE CONTERMINOUS UNITED STATES

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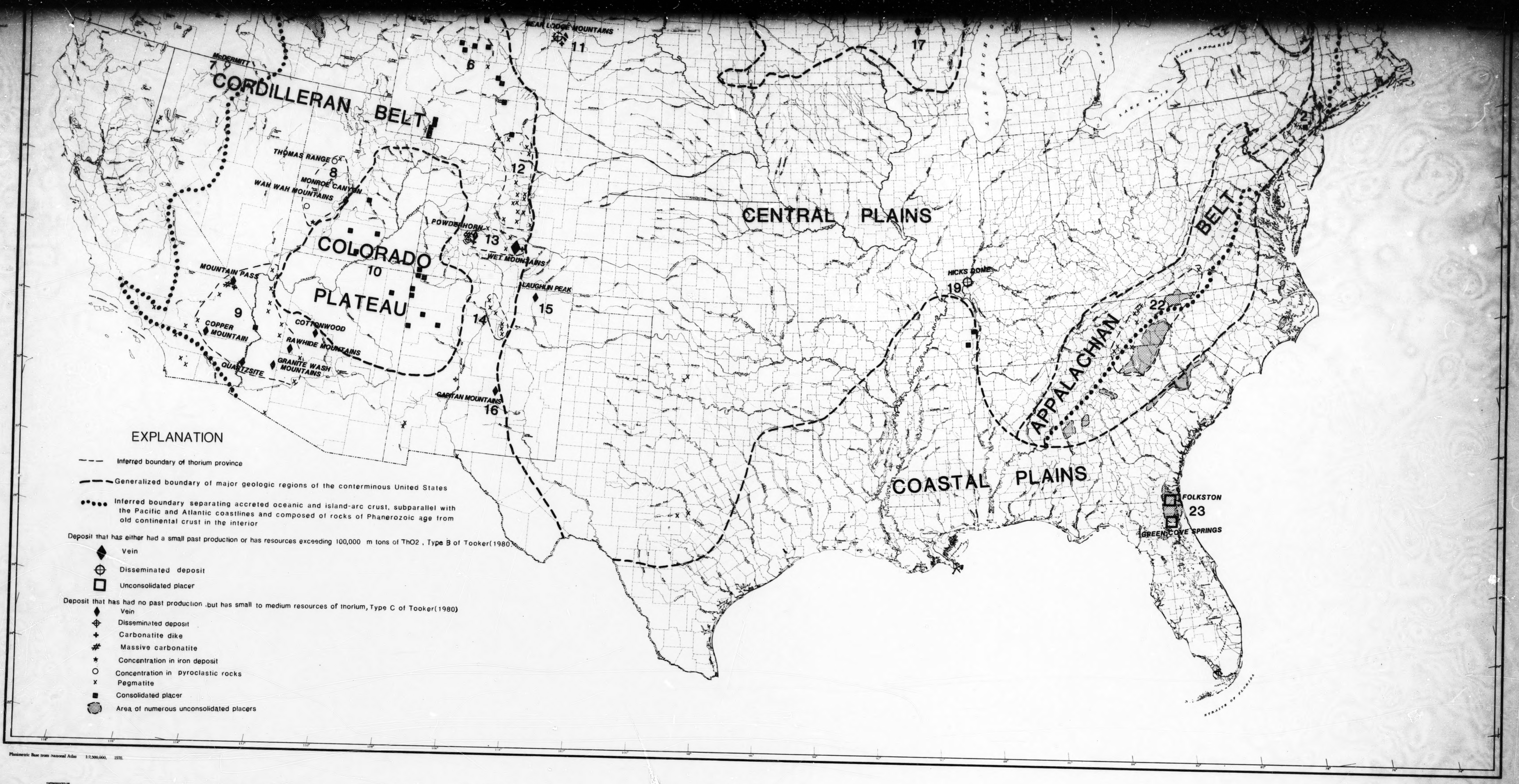
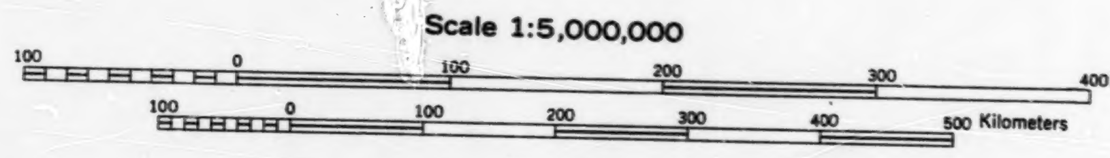
Mertie, J. B., Jr., 1975, Monazite placers in the [illegible]

Table 1.--Location, types of deposits, estimates of resource potential, status of resource information, and principal sources of information of thorium resources in the conterminous United States

Map no.	Area location		Geologic types of deposits¹	Preliminary estimates of resource potential			Status of geologic resource information		Selected sources of geologic and resource information
	State or States	Area		High	Medium	Low	Adequate	Insufficient	
1.	Idaho	Hall Mountain	V	X		X			Staatz (1979b)
2.	Idaho	Idaho batholith	I, X	X			X		Staatz and others, 1980
3.	Idaho and Montana	Lemhi Pass area	IV, V, VIII, IX	X			X		[illegible], 1980, [illegible] Staatz and others, 1979
4.	Montana	Northwest edge of Great Plains	II		X		X		
5.	Montana	Bearpaw Mountains	IV, IX		X		X		[illegible]
6.	Wyoming	Central Wyoming	II, VIII	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]


McDERMITT
7
CORDILLERAN BELT
6
BEAR LODGE MOUNTAINS
11
17
THOMAS RANGE
8
MONROE CANYON
WAH WAH MOUNTAINS
12
POWDERHORN
13
WET MOUNTAINS
COLORADO
10
PLATEAU
MOUNTAIN PASS
9
COPPER MOUNTAIN
QUARTZSITE
COTTONWOOD
RAWHIDE MOUNTAINS
GRANITE WASH MOUNTAINS
14
LAUGHLIN PEAK
15
CAPITAN MOUNTAINS
16
CENTRAL PLAINS
HICKS DOME
19
LAKE MICHIGAN
BELT
APPALACHIAN
22
COASTAL PLAINS
FOLKSTON
23
GREEN COVE SPRINGS
EXPLANATION
Inferred boundary of thorium province
Generalized boundary of major geologic regions of the conterminous United States
Inferred boundary separating accreted oceanic and island-arc crust, subparallel with the Pacific and Atlantic coastlines and composed of rocks of Phanerozoic age from old continental crust in the interior
Deposit that has either had a small past production or has resources exceeding 100,000 m tons of ThO2, Type B of Tooker (1980)
Vein
Disseminated deposit
Unconsolidated placer
Deposit that has had no past production but has small to medium resources of thorium, Type C of Tooker (1980)
Vein
Disseminated deposit
Carbonatite dike
Massive carbonatite
Concentration in iron deposit
Concentration in pyroclastic rocks
Pegmatite
Consolidated placer
Area of numerous unconsolidated placers
118°
116°
114°
112°
110°
108°
88°
86°
84°
82°
80°
78°
76°
74°

Planimetric Base from National Atlas 1:7,500,000, 1970.



PRELIMINARY MAP OF THE THORIUM PROVINCES IN THE CONTERMINOUS UNITED STATES

BY

Mortimer H. Staatz and Theodore J. Armbrustmacher

1982

INTRODUCTION

The map is part of the atlas of metal and nonmetal provinces in the conterminous United States (Tooker, 1980) and shows the locations of known deposits and selected occurrences of thorium. Thorium is used primarily as a component of incandescent gas mantles, in magnesium-base, high-temperature alloys, in refractories, and in other chemical, electronic, and metallurgical applications. Domestic consumption of thorium in 1975 (the base year for the atlas survey, Tooker, 1980) was about 50 tons of ThO_2, of which 35 tons were consumed in nonenergy-related uses (Smith, 1977, p. 1368). Thorium is also used in two domestic nuclear reactors, the high-temperature gas-cooled reactor (HTGR) at Fort St. Vrain, Colorado, and the experimental thorium-fueled light-water breeder reactor (LWBR) at Shippingport, Pennsylvania.

Past production of thorium in the United States in recent years has been chiefly from beach placers in Florida and Georgia where monazite was recovered as a byproduct of titanium mining. Monazite production ceased in this area in 1978 (Staatz and others, 1980, p. 4). The immediate future of domestic thorium production is closely tied to the nuclear power-generating industry and depends upon whether, and to what extent, thorium-fueled reactors are used in generating electrical power.

Thorium is found in at least 30 minerals, but only monazite ((Ce, La, Nd, Th) PO_4), thorite ($ThSiO_4$), brockite ((Ca, Th, Ce)$PO_4 \cdot H_2O$), and euxenite ((Y, Ca, Ce, U, Th) (Nb, Ta, Ti)$_2$ O_6) are likely to be sources of future production. The atomic radius of thorium is similar to that of both uranium and the rare earths, and thorium may replace these elements. Thorium and uranium commonly occur together in pegmatites, some granitic rocks, pyroclastic rocks, and in a few veins (like those found in the Bokan Mountain district, Alaska). For the most part, however, thorium deposits occur in different environments than do uranium deposits, and are more commonly associated with the rare earth elements.

Resources of thorium are large compared to any contemplated use over the next 30 years. Total known thorium oxide resources of the United States exceed 2,600,000 in tons (Staatz and others, 1979, 1980). These resources could supply a growing electrical generating industry for many years.

Thorium occurs in the conterminous United States in unconsolidated placers, consolidated placers, massive carbonatite, carbonatite dikes, veins, disseminated deposits, iron deposits, pegmatites, granitic rocks, pyroclastic rocks, and metamorphic rocks. Placers have been the principal source of thorium in the United States. Most of the thorium recovered in the past has come from beach placers, although stream placers have also been an important source. These two kinds of placers are considered as one type in this paper (unconsolidated placers), and are separated from older placers that are now part of a sandstone or conglomerate (consolidated placers). Massive carbonatites contain only minor amounts of thorium and are a probable byproduct source of this element. Carbonatite dikes may also contain thorium, but because of their smaller size need to be of higher grade to be considered a resource. Veins commonly are associated with alkaline rocks and are one of the highest grade sources of thorium. Generally they contain thorium and rare-earth minerals along with iron and manganese oxides in a gangue of quartz and/or potassium feldspar. Disseminated deposits are large low grade bodies in which thorium and rare-earth minerals are found in numerous veinlets cutting breccia or igneous rocks. Thorium is also found in some phosphatic iron deposits, where it occurs with rare earths in apatite. (In areas, such as Mineville, New York, which contain both phosphatic and nonphosphatic iron deposits, thorium occurs only in the phosphatic ores (McKeown and Klemic, 1956, p. 14-16). A few pegmatites in some pegmatite districts contain concentrations of thorium-rich minerals. Small amounts of thorium-bearing minerals are also scattered through other granitic rocks. Thorium has been reported in analyses from pyroclastic rocks in Utah and Nevada, but little is known of this type of deposit. Metamorphic rocks commonly contain thorium in the mineral monazite. Higher grade metamorphic rocks contain both more monazite and monazite containing a higher thorium content than do lower grade metamorphic rocks (Overstreet, 1967, p. 2). Higher grade metamorphic rocks, although rarely a resource themselves, are the principal source of monazite found in most placers in the world.

The map was compiled chiefly from reports by Staatz and others (1979, 1980), Adams and others (1980), Olson and Adams (1962), and from data contained in our files. Basic concepts and definitions of resource-related terms are taken from Tooker (1980).

Distinguishing Map Features

The map shows the distribution of various types of thorium deposits in the conterminous United States. Each variety has different potential, both as to present or future production. Some types are large low-grade sources of thorium, other types contain only small amounts of high-grade thorium. Grade of the deposits is of course an important factor in any future production, but the future of any deposits is not dependent entirely upon grade. Some high-grade deposits, like most pegmatites and some veins, are unimportant because of their small size. Some very low-grade deposits, on the other hand, may be important because they are large, and because thorium can be produced as a by-product of other metals. An example of this type of deposit is the beach placers of northern Florida, which are mined principally for titanium. Here monazite was recovered at Green Cove Springs from a deposit that contained only .0083 percent thorium oxide (Staatz and others, 1980, p. 6-7).

No single set of symbols will show all the variations that are likely to influence the production potential of all deposits. We have used both the shape and the size of the symbol to give as much information as possible. The shape of the symbol indicates the type of deposit; nine different types of deposits are shown on the map. They are: (I) unconsolidated stream or beach placers, (II) consolidated or fossil placers, (III) massive carbonatites, (IV) carbonatite dikes, (V) veins, (VI) disseminated deposits, (VII) concentrations in iron deposits, (VIII) pegmatites, and (X) concentration in pyroclastic rocks. A few occurrences that lack economic potential, such as bostonite dikes at Central City, Colorado, and allanite [illegible] near Hamilton, Bighorn Mountains, Wyoming, are not included on the map. Trace amounts of thorium that occur in granitic rocks in some areas may be important indicators of thorium deposits in a particular region. Such granitic rocks do not have an economic potential in the foreseeable future and are not shown on the map. Thus, occurrences such as the Conway Granite in New Hampshire, averaging about 59 ppm ThO_2, are not shown. They are, however, listed in table 1 in those areas containing other thorium deposits.

The shapes of the symbols in some cases take into account physical features which affect the cost of mining or milling the ore. For example, placers are divided into unconsolidated and consolidated. The cost of processing hard well-consolidated placers, like those that occur in the Goodrich Quartzite near Palmer, Michigan (map no. 18), or numerous sandstone beds from the Upper Cretaceous of Wyoming, Colorado, Utah, and New Mexico (map no. 10), is many times that of treating unconsolidated alluvial or beach placers. For economic reasons, carbonatites are divided into carbonatite dikes and massive carbonatites. Carbonatite dikes may have the same thorium grade and mineralogy as a massive carbonatite, but the difference in size makes the latter more economical to mine.

The size of the symbol indicates whether a deposit is a small producer or deposit with great potential, type B; or deposits having a small or medium potential, type C. Type A deposits, active mines that had substantial production in the base year 1975 (Tooker, 1980), are not found in the conterminous United States. Type B includes small present and past producers, such as Bear and Long Valleys, Idaho (map no. 2); Folkston, Georgia (map no. 23); and Green Cove Springs, Florida (map no. 23). In all of these deposits the thorium is but a minor byproduct. At these localities thorium recovery was dependent on the recovery of rare earths, and the rare earths were in turn a byproduct of titanium oxide and zircon at Folkston and Green Cove Springs, and of niobium at Bear Valley. Two large disseminated deposits, Bear Lodge Mountains and Hicks Dome (map no. 11 and 19), are also included in type B because of their potential as future producers. Knowledge of this type of deposit is relatively new, being first described by Staatz, and others (1979, p. 20-27). These deposits contain large resources of thorium and rare-earth elements. This type of deposit is analogous to the porphyry-type copper and molybdenum deposits.

One of the most common types of thorium deposits is that found in pegmatites. The thorium content of the entire pegmatites, however, is small. Thorium-bearing pegmatites are probably most important in delimiting provinces in which thorium is available to form other types of deposits. The location of the thorium-bearing pegmatites shown on the map was largely derived from a compilation made by Adams and others (1980).

Relation to rare-earth elements

Thorium commonly occurs with rare-earth elements in areas containing alkaline rocks such as massive carbonatites, carbonatite dikes, disseminated deposits, or veins. The total rare-earth to thorium ratios in these districts are highly variable, but in general thorium is much less plentiful than rare earths in the carbonatites, and somewhat more abundant than rare earths in veins. The two also occur together in apatite in iron deposits. Here, rare earths are much more common than thorium.

Description and evaluation of thorium provinces

Province boundaries are drawn around areas where known primary thorium deposits are most abundant. They indicate areas in which thorium deposits are fairly common and, presumably, the crust contains above average thorium. Deposits may be all of one type, but the area is more favorable if a variety of deposits of different ages occur. Multiple deposit types that formed at several times is good evidence of the above normal thorium content of the underlying crust. The boundaries of these areas are made on available data and can be extended if new deposits are found.

The deposits and occurrences and their potential as future domestic source of thorium are evaluated in table 1 and shown on the map. The highest potential for thorium deposits occurs in the Lemhi Pass area (map no. 3) and in the eastern part of the Cordilleran Belt. Another area, which seems to have considerable potential but is difficult to evaluate, is the Great Plains and its broad areas of flat-lying sedimentary rocks. Thorium deposits have been found here in a few places where these rocks have been intruded by alkaline igneous rocks, such as at Laughlin Peak (map no. 15), Bearpaw Mountains (map no. 5), Bear Lodge Mountains (map no. 11), and Hicks Dome (map no. 19).

Most of the occurrences shown in the Cordilleran Belt are in old continental crustal rocks. A large proportion are either Precambrian in age or in rocks which have been intruded into rocks of Precambrian age. Only a few hard-rock deposits are found along either the Pacific or Atlantic coasts, in the oceanic or island-arc crusts that were added to the old crust during the Phanerozoic. Oceanic crust appears to be unfavorable for the occurrence of large primary thorium deposits.

Certain provinces have greater potential for thorium production than others. The most favorable provinces are those in which deposits are related to alkaline rocks: massive carbonatites, disseminated deposits, veins, and carbonatite dikes. Provinces and areas that contain these types of deposits are the Lemhi Pass area (map no. 3), Bearpaw Mountains (map no. 5), Mohave Desert (map no. 9), Bear Lodge Mountains (map no. 11), Powderhorn-Wet Mountains (map no. 13), Laughlin Peak (map no. 15), Capitan Mountains (map no. 16), and Hicks Dome (map no. 19). Not all of these areas contain large deposits, but they contain over 90 percent of the domestic thorium resources as tabulated in two recent resource studies (Staatz and others, 1979; Staatz, and others, 1980). These types of deposits occur in six thorium provinces and as occurrences in the Cordilleran Belt east of the boundary separating continental rocks from accreted oceanic crust. They also occur in four widely scattered localities within the Great Plains and in the Wausau area (map no. 17) on the Precambrian shield. None are known in the Appalachian Belt or Coastal Plains.

Certain types of deposit are less favorable as future producers because of their small size. Thus, provinces noted by map numbers 12, 14, and 21, where pegmatites are common, are not as favorable as those in which alkaline rocks are present. Size alone, however, will not determine which deposits will become producers. Some of the unconsolidated placers, because of their ease of handling, low cost of separation, and presence of byproducts, will probably be mined before some larger and higher grade deposits. Thorium in apatite from iron mines can also be easily separated. Iron tailings piles in the Mineville, New York area (map no. 20) contain approximately 726,000 m tons of apatite (Staatz and others, 1980, p. 39) that contain approximately 0.13 percent thorium (McKeown and Klemic 1956, p. 9).

Placer deposits may be of little aid in outlining thorium province boundaries. In some places, as in the Idaho batholith (map no. 2) and the Piedmont province (map no. 22), they are but little removed from the granitic and metamorphic rocks from which they are derived. In these two areas, the higher grade placers help outline these provinces. In other areas, the placers are far removed from their original source. Some of the monazite derived from the Piedmont was carried down rivers to be deposited in formations ranging from Late Cretaceous to Holocene in age (Mertie, 1975, p. 11). These rocks have since been eroded and a second generation of placers formed. These placers are shown on the map southeast of province no. 22 along the west edge of the Coastal Plain. Some of the monazite originally derived from the Piedmont was carried to the ocean where it was transported southward by longshore currents to southern Georgia and northern Florida. Here, alluvial placers formed in [illegible] and Holocene times. The monazite in these deposits is far removed from the site of its original formation, and hence the presence of monazite in these placers does not make the surrounding area favorable for primary thorium deposits. Consolidated placers are common in the Upper Cretaceous sandstones of central Wyoming (map no. 6) and the Colorado Plateau (map no. 10). The monazite in these placers also is apparently widely separated from its original source, and these two areas are not considered primary thorium provinces.

This report is preliminary and has
not been reviewed for conformity
with U.S. Geological Survey editorial
standards and stratigraphic nomenclature.

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Background information relating to this map and others in the Atlas of Metal and Nonmetal Provinces in the Conterminous United States is published as U. S. Geological Survey Circular 792 (Tooker, 1979), available free of charge from the U. S. Geological Survey, Branch of Distribution, 1200 Eads St., Arlington, VA 22202.

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Map no.	Area location		Geologic types of deposits[1]	Preliminary estimates of resource potential			Status of geologic resource information		Selected sources of geologic and resource information
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2.	Idaho	Idaho batholith	I, X	X			X		Staatz and others, 1980
3.	Idaho and Montana	Lemhi Pass area	IV, V, VIII, IX	X			X		Staatz, 1972a, 1974, 1979; Staatz and others, 1979
4.	Montana	Northwest edge of Great Plains	II		X		X		
5.	Montana	Bearpaw Mountains	IV, IX		X		X		Schmidt and others, 1964
6.	Wyoming	Central Wyoming	II, VIII			X		X	Dow and Batty, 1961
7.	Nevada	McDermitt area	X		X		X		
8.	Utah	Southwestern Utah	V, VII, VIII, X			X		X	
9.	California, Arizona and Nevada	Mojave Desert	II, III, IV, V, VIII			X		X	Olson and others, 1954; Shawe, 1953; Adams and others, 1980
10.	Colorado, Utah, Arizona, and New Mexico	Colorado Plateau	II		X		X		Dow and Batty, 1961
11.	Wyoming	Bear Lodge Mountains	IV, V, VI	X			X		Staatz (in press)
12.	Colorado and Wyoming	Front Range	II, VIII			X		X	Adams and others, 1980
13.	Colorado	Powderhorn-Wet Mountains	III, IV, V, VI, VIII		X			X	Christman and others, 1959; Armbrustmacher, 1976; Hedlund and Olson, 1973; Olson, 1974; Armbrustmacher, 1980; Armbrustmacher, 1979; Olson and Hedlund, 1981; Olson and Wallace, 1956
14.	New Mexico	Petaca-Harding	VIII		X		X		Adams and others, 1980
15.	New Mexico	Laughlin Peak	V		X		X		Staatz, 1974
16.	New Mexico	Capitan Mountains	V		X		X		Do.
17.	Wisconsin	Wausau	V		X		X		Do.
18.	Michigan	Palmer	II	X			X		Gair, 1975
19.	Illinois	Hicks Dome	VI	X			X		Heyl and others, 1966; Staatz and others, 1979
20.	New York	Adirondack Mountains	VII, VIII		X			X	McKeown and Klemic, 1956
21.	New York and New Jersey	Reading Prong	II, V, VII, VIII		X			X	Adams and others, 1980
22.	Virginia, North Carolina, South Carolina, Tennessee, and Georgia	Piedmont Province	I, VIII, IX			X	X		Do. Overstreet, 1967; Overstreet and others, 1959
23.	Florida and Georgia	Northeast Florida and Southeast Georgia	I		X		X		Staatz, and others, 1980

[1] Index to geologic types of deposits and occurrences:
I. Unconsolidated stream or beach placers
II. Consolidated or fossil placers
III. Massive carbonatite
IV. Carbonatite dikes
V. Veins
VI. Disseminated deposit
VII. Concentrations in iron deposits
VIII. Pegmatites
IX. Trace amounts in granitic rocks
X. Concentration in pyroclastic rocks